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ABSTRACT

This review of research related to college and university science teaching and learning is based upon reports published from 1965 through 1967 and contained in the collection of the ERIC Information Analysis Center for Science, Mathematics, and Environmental Education. The 77 studies are abstracted under the following headings, with a short summary of the major generalizations made for each section: Instructional Procedures; Teacher Education; Equipment and Materials; Curriculum; Achievement; Science and Society; Administration and Supervision; Evaluation and Educational Objectives; and Teacher and Student Characteristics. A general summary comments upon weaknesses found in the research, identifies areas that need additional research, and comments on the lack of relationship between college courses and the secondary school science courses that students have taken. The bibliography includes ordering information for those studies cited that are available from the ERIC Document Reproduction Service. (AL)

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SCIENCE EDUCATION INFORMATION

REPORTS

RESEARCH REVIEW SERIES - SCIENCE
PAPER 3

A SUMMARY OF RESEARCH IN SCIENCE EDUCATION FOR THE YEARS OF 1965-67, COLLEGE LEVEL

by
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SCIENCE EDUCATION INFORMATION REPORTS

The Science Education Information Reports are being developed to disseminate information concerning documents analyzed at the ERIC Center for Science Education. The Reports include five types of publications. General Bibliographies are being issued to announce most documents processed by the Center for Science Education. These bibliographies are categorized by topics and indicate the availability of the document and the major ideas included in the document. Special Bibliographies are being developed to announce availability of documents in selected interest areas. These bibliographies will list most significant documents that have been published in the interest areas. Guides to Resource Literature for Science Teachers are bibliographies that identify references for the professional growth of teachers at all levels of science and mathematics teaching. This series will include six separate publications. Occasional Papers will be issued periodically to indicate implications of research for science and mathematics teaching. Research Reviews will be issued to analyze and synthesize research related to science and mathematics education over a period of several years.

The Science Education Information Reports will be announced in the SEIAC Newsletter as they become available.

RESEARCH REVIEWS - SCIENCE

Research Reviews are being issued to analyze and synthesize research related to the teaching and learning of science completed during a two-year period of time. These reviews are organized into three publications for each two-year cycle according to school levels--elementary school science, secondary school science, and college science.

The publications are developed in cooperation with the National Association for Research in Science Teaching. Appointed NARST committees work with staff of the ERIC Center for Science Education to evaluate, review, analyze, and report research results. It is hoped that these reviews will provide research information for development personnel, ideas for future research, and an indication of trends in research in science education.

Your comments and suggestions for this series are invited.

Robert W. Howe
and
Stanley L. Helgeson
Editors

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INTRODUCTION

This review is based on substantially all of the research studies in the area of college and university science teaching and learning reported between 1965 and 1967. All of these studies published during that time and contained in the ERIC files were considered for inclusion in the review. Only studies which failed to clearly communicate their objectives and surveys of the numbers of scientists and engineers required to fulfill specific projected national goals or professional needs were not included in the review. The reader is referred to the ERIC Information Analysis Center for Science Education for a bibliography related to these concerns.

There are many ways in which the different types of research findings can be placed into a survey review. They may be placed, for example, according to the kind of finding, or according to the context in which the research was done. Since we are aware that the users of this kind of research come from many fields, both within science education and within the various sciences, the findings contained in this review will be reported in terms of the context in which the research was done. These nine contextual subtopics are: (1) Instructional Procedures, (2) Teacher Education, (3) Equipment and Materials, (4) Curriculum, (5) Achievement, (6) Science and Society, (7) Administration and Supervision, (8) Evaluation and Educational Objectives, and (9) Teacher and Student Characteristics.

INSTRUCTIONAL PROCEDURES

During the 1965-1967 triennium, a great amount of work was done in the field of instructional procedures in the various sciences at the college level. Frequently mentioned among these kinds of considerations was the value of laboratory work. Postl (1965) conducted an investigation of the differences in achievement among students enrolled in a physical science course for general education conducted with and without laboratory work. Pre- and posttest scores on proficiency and reasoning were compared using F and t tests. No significant differences were detected between groups who did or who did not have individual laboratory work. Postl stated, however, that these experimental results do not produce a definitive answer to the question of whether general education science courses should be conducted without laboratory work, because the comparisons in achievement did not include benefits which may accrue from the laboratory alone.

Strope (1966) compared some differences in learning outcomes obtained by using factual and conceptual methods of teaching introductory college astronomy. Using a covariance design, the effects of treatment, sex, and college class level were observed on scores of the Test on Understanding Science, (TOUS), and a test constructed to measure mastery of astronomy concepts. Student attitudes were also surveyed. The attitude data indicated those students involved in the conceptual orientation section developed stronger interest in taking additional work in science than the others. TOUS scores differed little between the sections, and within sections. The achievement of males was higher than that of females, while TOUS scores were higher for higher college class levels.

Two approaches for teaching introductory meteorology for prospective teachers were developed and tested by Geer (1967). For the first group, data for learning about atmospheric conditions were based on student-made observations. For the second group, weather data were obtained from weather maps and charts released by the United States Weather Bureau. Two instructor-developed achievement tests, a standardized achievement instrument, and the Test on Understanding Science were used to compare treatment groups on (1) acquisition of basic facts and principles and facts related specifically to meteorology, (2) ability to interpret weather conditions, and (3) understanding of science. No significant differences between the treatments were obtained. The investigator concluded that both of these inductive methods were equally effective in reaching the objectives of introductory meteorology.

Donor (1965) conducted a study to determine if student drawing in biology laboratory affected ability to observe accurately, to think critically, and to gain and apply biologically oriented factual knowledge. Students in the same lecture course were randomly assigned to drawing and non-drawing laboratory sessions. To equalize observation time for biological specimens, the non-drawing group was required to answer a series of questions pertaining to the material observed. Both before and after a semester of study, both groups were administered a practical examination, the Watson-Glaser Critical Thinking Appraisal, and the Nelson Biology Test. For all of the tested variables, the non-drawers achieved greater gains. The author concluded that the results of this study showed that the practice of having students construct laboratory drawings in college biology does not contribute to specific learning in biology.

Schefler (1965) compared inductive and illustrative laboratories for teaching genetics in college biology. Methods were compared by analysis of students' interest and achievement scores on a genetics achievement test, the Test on Understanding Science, the Kuder Preference Form C, and a semantic differential science attitude instrument. Two instructors were involved in the study. Each taught a section of illustrative laboratory and a section of inductive laboratory. Covariance on gain scores of the variables employed showed no significant differences on achievement, interest, knowledge of science and scientists, and science attitude scores. There was, however, a specific instructor effect noted. The evidence does not indicate that the inductive laboratory is a better or poorer approach than the illustrative laboratory, but emphasizes the need for research concerned with both methodological teacher effects on learning.

Kuhn (1967) investigated the effect of advanced organizers on the acquisition and retention of information in college introductory biology. A sample of 580 students enrolled in biology for elementary teachers was divided into two groups, one of which was given an advanced organizer prior to instruction, while the other was provided with an historical passage of the same length. Kuhn found that the acquisition and retention of knowledge level material was enhanced by using the organizer. The organizer also appeared to work particularly well with persons of low academic ability.

Bradley (1965) compared lecture-demonstration and individual laboratory work in the physical science part of a general science for general education course, using uni-variant and factorial designs. He compared the final grade in the physical science part of the course and the College Qualification Test, Form T, scores (CQT-T) for the treatment groups. No differences appeared between the methods, sexes, placement on the CQT-T, and students with or without previous laboratory science courses. Bradley states that these findings suggest that for institutions where laboratory facilities are in short supply, the laboratory may well be omitted in favor of a lecture demonstration approach if the objectives desired were the same as his.

The effects of specific kinds of college physics on critical thinking were examined by Henkel (1965). Three small groups of introductory physics students, one using a discussion with discovery laboratory, a second using a traditional lecture-recitation approach, and a third group using a discussion with the usual laboratory method, were included. The groups were compared on the Watson-Glaser Critical Thinking Appraisal and standardized achievement tests. The discussion group using a discovery laboratory gained the most in critical thinking scores. The traditional group gained most in achievement as measured by the instruments.

Ricker (1965) compared the effectiveness of four methods of teaching magnetism in a basic college physical science course. Methods compared were (1) lecture only,(2) lecture and teacher-demonstration,(3) lecture and student experimentation, and (4) lecture and programmed learning. No significant statistical differences were obtained from pre- to posttest or on retention achievement tests. The investigator concluded that since these methods were equally effective means of instruction, the most efficient namely, the lecture approach, was the most productive.

Rickert (1967) tested the hypothesis that the ability to think critically is improved significantly in a physical science course which gives students opportunities to analyze problems, examine assumptions, collect and organize data and test hypotheses. Using the ACE Test of Critical Thinking, (Form G) to compare the experimental approach with standard survey courses in physical science and freshman physics, Rickert found that the experimental approach was more effective as a means of developing the ability to think critically.

A group of 31 college students enrolled in a general physics course, including laboratory, were compared by Whitney (1965) with a group of the same number of students for whom laboratory was not a part of the course. The groups were matched on IQ, ACT composite scores, ACT natural science scores, and Kuder scientific scores. After one semester of work tests were administered for the following traits: fluency of ideas, flexibility of ideas, originality of ideas, elaboration of ideas, thinking introversion, theoretical orientation, complexity, autonomy, impulse expression, religious-liberalism and masculinity-femininity. No significant differences were detected between the laboratory and non-laboratory oriented groups. It was concluded that for the sample used, the conventional college physics laboratory did not affect scientific creativity.

McAda (1966) developed and evaluated multi-media approaches for college freshmen chemistry laboratory which attempted to minimize the role of the instructor and which utilized mechanical means to present routine instruction. Techniques evaluated included: tape-slides, synchronized review, printed directions, audio-tapes, 8 mm. colored films, and problem-solving via tape-slide synchronized presentation. These instructional procedures were evaluated by means of student reactions, observation of student laboratory behavior, and examination of laboratory reports. Findings indicated that procedures employed served the function for which they were designed and also that they facilitated giving students practice in the types of thinking for which laboratory instruction in chemistry is designed.

Milne (1965) prepared and tested a set of programmed learning materials for introductory chemistry. The programmed materials group was compared with a group which received conventional laboratory-tutorial sessions. Analysis of variance on mathematics placement and chemistry achievement pretest scores showed no difference between the groups. Chemistry achievement gain scores were compared using achievement categories of recall of information, application of principles, and problem solving. The conventional group gained significantly more on recall of information while the programmed materials group gained significantly more on application of principles. No differences were observed on problem solving. Questionnaire responses indicated favorable reception of the programmed learning materials by their users.

The effectiveness of three methods for teaching inquiry skills in a unit on volumetric analysis in first year college chemistry was tested by Petrie (1967). One group was taught by a method in which an instructor demonstrated laboratory techniques before students began experimental work. In a second group, the instructor demonstrated laboratory techniques by applying models for structure and problem solving behavior. In a third group, the model application was followed by having students conceptualize problem solving behaviors through verbal discourse with colleagues. Analyses of variance of scores from tests specifically constructed and administered after each laboratory session indicated a significant difference in favor of the third method. The third group also demonstrated higher scores than the other groups on the <u>Watson-Glaser Critical Thinking Appraisal</u>.

Zingaro (1966) compared a traditional method with an inductive method of teaching college physical science laboratory for college sophomores. A physical science achievement test, a physical science critical thinking appraisal, the <u>Test on Understanding Science</u> (TOUS), and the <u>Watson-Glaser Critical Thinking Appraisal</u> were compared for the treatment groups by the method of analysis of variance. Differences on the <u>Watson-Glaser</u> and <u>TOUS</u> instruments involved instructor effects. No other significant differences were observed between the treatment groups on any of the measures employed. Zingaro concluded that the inductive laboratory was no less effective than the traditional approach with reference to the test measured achievement.

In summary, it may be seen from these studies of the instructional procedures in college level science courses with emphasis on laboratory, that a great deal of redundancy exists. It has been shown by most of these studies, that laboratory work is not particularly helpful in achieving the course objectives of traditional courses as measured by the instruments used. If laboratory work is considered in more depth, particularly if the kind of thinking which laboratory work is designed to produce is analyzed, then there is some evidence for the choice of an inductive approach over an approach in laboratory designed for illustration or validation of principles presented in lecture. Those studies which dealt with multi-media and programmed learning as adjuncts to traditional laboratory courses, have shown that these kinds of aids make traditional laboratory work easier to administer and control without any loss in effectiveness.

On the basis of the research reported it seems that more effective approaches for laboratory work than those usually used for college courses are available.

TEACHER EDUCATION

Several studies dealing with the background abilities of candidates for secondary school teaching of science pertinent to their college level training, and also studies regarding specific methods courses in science are contained in this section.

The extent to which prospective science teachers are proficient in critical thinking and possess understanding of science consistent with the practicing scientists was studied by Craven (1966). The samples used were composed of social science education freshmen, science education freshmen, elementary teacher candidates, social science teacher candidates, and in-service science teachers. Critical thinking in science knowledge was measured for all participants using the Cornell Critical Thinking Test (CCTT) and the Test on Understanding Science (TOUS). Combined verbal and mathematical mean scores on the Scholastic Aptitude Test (SAT) and accumulated grade point averages were used to control academic aptitude and achievement abilities. It was concluded that critical thinking abilities of science teacher candidates were significantly greater than all other groups tested, except the social science teacher candidates. Critical thinking scores were not significantly correlated with the number of science credits or science grade point averages.

Within science teacher candidates group, no differences were observed by Craven for sub-groups selected on the basis of college science achievement, biology or physical science orientation, or number of quarter hours of mathematics instruction. All groups revealed misunderstandings of the nature of science models, hypotheses, theories and laws on the TOUS. Those misunderstandings were more numerous for those who had had little college science. However, it was concluded that understanding of science as measured by the TOUS was not a major learning outcome of science courses at the college level.

Molchen (1967) used interaction analysis, student teacher intention, role perceptions, and self-perception of ideas as part of an approach to study the outcomes of the student teaching experience on prospective teachers. Using a sample of 26 science teaching interns and 26 apprentices in the Harvard MAT program Molchen compared the internship program to the apprenticeship program. He found significant differences on many of the variables between interns and apprentices. Significant differences were also shown between interns in the fall and spring semesters, as well as interns assigned to junior high schools as compared to those assigned to high schools.

Adalis (1965) studied what is and what should be the relative degree of subject matter importance in the preparation of secondary school biology teachers in West Virginia as perceived by in-service teachers and high school biology department chairmen. Mean responses and frequency counts were made of 11 subject-matter areas from questionnaires sent to teachers and department chairmen. Adalis concluded that the two most important areas for pre-service education in biology were general zoology and botany, and the two least important areas were astronomy and geology. From the teachers' view, the areas of subject matter emphasis in pre-service preparation were in descending order: general zoology, field biology, general botany, general chemistry, physiology, ecology, genetics and conservation. Teachers felt that physics, geology and astronomy should receive little or no emphasis. Chairmen rated physics higher than did the teachers and physiology lower.

Sanders (1967) conducted a questionnaire study of the member companies of the Aero-Space Industry Association of America to determine which kinds of materials and experiences that this industry could provide that would be of value to teachers. It was found that teachers should experience field trips to the industry, but that children's trips, to be beneficial, require very special planning. Use of industrial representatives as speakers and part-time instructors was rated as important. Trade journals and teacher membership in space organization were viewed as valuable, both for content information and career guidance. It was suggested that college courses in aero-space education be developed.

Tillery (1967) investigated the use of student self-evaluation of objectives in a methods course in elementary science. He compared the validity and reliability of a specially developed Student Evaluation of Achievement instrument (SEA) for lecture and non-lecture modifications of the course. Using Pearson Product Moment correlation for reliability and correlation with objective final examination scores, he found an overall validity coefficient of 0.43 and a reliability coefficient of 0.94; both were significant at or beyond the 0.01 level of confidence. The lecture course SEA validity was 0.25, while the non-lecture course SEA validity was 0.69. Tillery suggested that the non-lecture approach which emphasized discovery methods was a better way of presenting a science methods course.

The results of an in-service course which presented physical science from a historical prospective were analyzed by Lavach (1967). Participants were given the Test on Understanding Science (TOUS), a specially designed test on the historical development of science, and a test on facts about science. Significant gains in tested achievement were made in understanding the historical development of science as well as in understanding the methods, aims, and overall nature of science. No relationship between achievement gains and prior teaching-learning experiences were found.

No general conclusion can be made regarding what should be the future of teacher education at the university and college level from the research attempts reported during this period.

EQUIPMENT AND MATERIALS

In this section, studies regarding science apparatus and equipment used in instruction in science are described. Only three such studies were in evidence for the 1965-67 period. Tanner (1967) developed and evaluated a "scrambled book," or programmed work book, for use in teaching conceptual areas of maps, dimensions, gravity, tides, isostasy, running water, and coasts and oceans in freshmen college geology. Classes were divided so that students either attended lectures on these topics or used the work book as a sole source of instruction. Data indicated that students who used the "scrambled book" achieved at the same levels as those who attended lectures. Questionnaire responses showed that students preferred the lectures to the work book. Recommendations for using the work book as an adjunct to lectures were discussed.

Requa (1966) compared synchronized 35 mm. colored slide audio tape materials for the introduction of college biology work with standard verbal demonstration methods. Scores on an achievement test designed to measure laboratory observation and procedures were analyzed using the Mann-Whitney U Test to determine if the tape slide method was superior to the standard method. A difference, significant at the 0.035 level, of confidence, favored the slide tape method and an opinion survey indicated that students reacted more favorably to the slide-tape presentation.

Hayden (1968) developed colored motion film presentation materials for teaching serial sections in human oral histology and embryology for medical and dental students. Analyses of variance and co-variance of achievement data showed no significant differences between motion picture film and slide versions of the anatomical sections. A Chi-square analysis, however, on non-cognitive items indicated that the students preferred the films to the slides as a means for studying the three dimensional concepts.

In this section we have seen three somewhat similar research projects dealing with materials of science instruction. It would seem that more studies, particularly related to films or video-tapes for introduction of laboratory exercises and for conveying specific concepts, would be very helpful.

THE CURRICULUM

Several kinds of studies related to college science programs and courses were reviewed. Essentially those that appeared were: studies related to teaching science as inquiry, studies related to the evaluation of science programs and continuing education, and studies related to the junior college as a center for the study of science.

Evans (1965) conducted a study of the behaviorial objectives of science for general education. He presented the view that science for general education should provide a series of experiences in inquiry. Materials and activities were developed for use in a college general education science course based upon the following five criteria: (1) the specific content of the course presents a real description of the methods used in the sciences such that it allows for activities directed at observation, record keeping, development of relationships, building of concepts, problem solving, and research; (2) the method of presentation conforms to the essentials of scientific inquiry; (3) the design of the course conforms to the need for interrelatedness with other courses; (4) the course design specifically provides for definition of outcomes to be employed in evaluating student achievement; (5) the course design is amenable to modification based on the identification from evaluation.

Paige (1965) studied the differences in evaluative judgment made on science programs by students, faculty, and administrators, of the colleges operated by the African Methodist Episcopal Church. A sample of individuals from each category used an inventory to rate the science program in his college. Paige found that all of the administrators, faculty, and students assigned the largest weight in rating to financial support. Students weighed the area of instruction as being the second most important consideration, while the faculty's second consideration was administrative practices and procedures. The investigator recommended that colleges of this type carefully consider building a sound fiscal policy as a major means of improving the science program.

Pollock (1966) developed a profile of junior college biology departments from a questionnaire study. In this study, he compared private and public junior colleges. He found that private junior colleges had smaller classes than public junior colleges. The teaching load was less in the private schools, and annual expenditures per student were larger in the public schools. The private college instructors were generally less experienced and had less educational background than those in the public schools.

A questionnaire study was conducted by Condell (1965) to obtain data relative to the uniformity and adequacy of biology programs for the public junior colleges in Minnesota. Categories listed for analysis were: faculty qualifications, facilities and equipment, library acquisitions, teaching loads, course offerings, and budgets. Condell concluded that, based on the objective criteria employed, specific inadequacies appeared in all of the categories. Moreover, there was little evidence to suggest any kind of instructional uniformity throughout the junior colleges in the state of Minnesota.

Kochersberger (1965) compared the general biology achievement of students in community colleges to those at the university. An analysis of covariance of course achievement, with high school grade average and Nelson Biology Test scores as covariates, indicated that the university and community college did not differ significantly. Without statistical control of prior achievement, the university students achieved significantly better. When the achievement of above or below average students was compared between institutions, no specific differences were observed. Significant positive correlations were found between high school grade averages, the Nelson Biology Test scores, and course grades for both institutions. It was also found that overall lack of success in biology courses, as indicated by course grades of D or F, was greater at the university. In general, the community college student was less well prepared academically than his university counterpart, but he perceived his faculty and college to be more favorably disposed toward him.

Minner (1965) studied the background preparation and professional activities of faculty, the course structure, and the laboratory practices in introductory biology in Catholic junior colleges for women in the United States. With regard to faculty, it was found that few had doctoral degrees and none had received specific training for junior college teaching. Few instructors attended national conventions of biological organizations. The biology course itself was found to lack clearly formulated objectives. Descriptive analyses of course content indicated that human anatomy and animal classification received much more emphasis than biological processes, genetics, heredity and evolution. In the laboratory, equipment was in short supply. Little emphasis was placed on working with live specimens in open-ended experimentation. In general, Minner found little evidence in the organization and teaching of introductory biology in Catholic women's junior colleges different from that previously reported by others for other types of junior colleges. Research involvement and refresher course work were specifically recommended by Minner for faculty, while participation in specific organizations for college biology teachers was recommended for course improvement.

Moore (1965) conducted a questionnaire and interview study of content and organizational practices for introductory biology in 32 colleges which had students who took the advanced placement biology in high school. The major findings were that there existed a large variation in course content. Many institutions surveyed reported changing emphasis from phylogeny to physiology and molecular biology. A wide variety of sequencing and time allotments was in evidence. While ecology and genetics were becoming centralizing themes, little time seemed to be spent on microbiology of immunity, sereology, radiation and space biology. The history of biology and the role of culture in human evolution also seemed to have lost time considerably over previous time allotments.

In summary, for those studies directed at the evaluation of a variety of education programs, the following were found: inquiry based courses should be evaluated behaviorally by listing the kinds of activities of an inquiry nature included in the course; to improve small college instruction in science, considerably more funds may be required for each college; within each college better fiscal policies are needed.

The junior colleges were studied in depth. With regard to science instruction, it would seem that junior college teachers require both more specific course work and research in science as well as more specific instruction in the teaching of junior college science courses. Junior colleges differ somewhat from universities, particularly on the basis of the level of preparation of the students, who seem to be academically poorer than that at the university. It appears that the junior college is an institution which is established to serve the needs of specific kinds of learners. Private junior colleges differed a great deal from public junior colleges, particularly on such things as class size and the preparation level and experience level of instructors. Considerably more research needs to be done on the characteristics of junior colleges, not only to describe the junior colleges, but also to examine the specific role science instruction plays therein.

Finally, in general biology instructional programs, it has been found that the biology curriculum is changing from a phylogeny oriented study to one aimed more at genetics and molecular biology.

Other aspects of curriculum are discussed in the following sections.

ACHIEVEMENT

A study, focused on the interpretation of the Strong Vocational Interest Blank (SVIB) for predicting the success of undergraduate engineers, was conducted by CoBabe (1967). The SVIB responses of freshman students who later continued in engineering, transferred to other curricula, or left the university were analyzed to determine whether the SVIB could be used to predict the students' subsequent success levels. Two methods of analyses were employed. The D-square statistics on the interest data was employed to produce hierarchical groups. The two groups in which interest profiles were most and least congruent to the expressed academic major were selected for study. An analysis of variance on cumulative grade point average with ability level held constant did not produce a significant F value. Multiple discriminant analysis was employed with three criterion groups: persisting engineering students, other students who continued to the degree level, and non-degree students. One of the discriminant functions containing SVIB items and ability variables significantly discriminated among these groups. The occupational preferences for the criterion groups were described with reference to the usual SVIB categories.

Bolte (1966) used multiple correlation techniques to analyze high school backgrounds of students who had taken college physics. Five of the twelve selected variables were found to be significant predictors of success in college physics. The best predictor was high school grade point average. High school rank in class occupied approximately the same place in the correlation. High school physics (few had had PSSC) was the least important of the five significant predictors. Other significant predictors were having had college freshman mathematics, college calculus, and chemistry. No relationships were found between high school mathematics and college physics achievements scores.

Fulwood (1965) conducted an ex post facto study of the possible relationships between selected academic and non-academic factors in achievement in introductory college physics. Whether or not college students had had high school physics did not significantly relate to success in college physics. Neither was the kind of high school physics course (PSSC, film-instructor approach, or several kinds of traditional approaches) related to college physics grades, while the amount of advanced high school mathematics was not related to college physics grades. Grades in high school mathematics, in general, were significantly related to college physics achievement. No relationships were found among college class standings, nature of college major, and whether or not the student took physics as a required or elective course, and physics course grades. The number of college mathematics courses taken was not significantly related to physics achievement, but the number of college chemistry courses was. Student ratings of their high school physics teachers' teaching ability was significantly related to their college physics grades. In a separate analytical study of high school physics teachers, their teaching ability and knowledge as rated by students were compared with the teachers college achievement in mathematics and physics. Both the college physics and college mathematics averages of the teachers were significantly related to teaching ability ratings. Teacher characteristics which related to high achieving students in college physics were a strong physical science background in college and high grades in physics in college combined with somewhat lower grades in college mathematics.

Gee (1967) investigated the effects of factors such as a student's curriculum major, sex, preparation in organic chemistry, marital status, employment, place of residence and study patterns on achievement in introductory college biology. Achievement was measured by course final examination raw courses, while the descriptive data were obtained from student questionnaires. Chi-square analyses significant at or beyond the 0.05 level allowed these conclusions: Enrollment in a particular major had no effect, but a commitment to the major significantly affected achievement. Marital status, student employment and student classification were not contributing factors, but prior work in organic chemistry was influential. Female students achieved at higher levels than males, and students residing off campus had higher levels of achievement. Consistent study patterns were also found to be beneficial.

Van Erdewyk (1967) investigated the variables characteristic of undergraduate students who persist in engineering, transfer from engineering, and drop out of college. Using achievement data (ACT Test Scores) high school and college grades, socio-economic descriptors and questionnaire responses on interest in and feeling toward engineering courses, several conclusions were made. Generally, persistors showed higher high school, college and test measured course achievement in mathematics and chemistry than transferring students and dropouts. Persistors also showed higher grade point averages than others at all semesters in college. Questionnaire responses indicated that more guidance information about the nature of engineering would have helped these undergraduates achieve at higher levels. Other findings relevant to interest in science and engineering, as well as decision-making processes involved in entering engineering or transferring from it, were reported and discussed.

Zansitis (1965) examined the extent to which an authoritative communication of a student's ability level will influence his subsequent test measured achievement in science. Three groups of students were employed in this study. The first were interviewed about their college entrance test courses and they were told they would do well in college science. The second group was interviewed in a neutral way as to a prognosis on their later science achievement. The third group was not interviewed. Scores on the sequential tests of Educational Process Science Test were analyzed by a Friedman Analysis of Variance. The analysis indicated that significant differences existed in that the first group achieved at higher levels than the second, and second achieved at higher levels than the third.

Zitelli (1967) compared the basic physical science achievement scores in astronomy, physics and chemistry units and gain scores of students when taught in a cooperative effort by specialists in each of these areas, with the achievement and gain scores of students taught by a single instructor. The results of this investigation were that the gain scores of students were independent of the method of instruction used. Even though some advantages were attributed to the cooperative effort by students, a considerative recommendation would be that the method of instruction to be used would be the one preferred by the teachers assigned to teach the course. Where both methods of instruction were used, there is some evidence to support the assignment of students by method of instruction to be used and the students college entrance board examination verbal scores, place of residence, rank in graduating class, or percent of the graduating class that go on to a four-year college. Therefore, it would seem that achievement is related to the kind of course that a person should be participating in.

A multiple regression analysis on demographic and academic variables was used by Gohn (1967) to determine which best predicted success in veterinary medicine. Using pre-clinical grade point average as a criterion variable, he found that pre-veterinary cumulative grade-point average at the time of selection, along with grades in organic chemistry and introductory physiology, produced an equation of best fit. Similarly, with clinical cumulative grade-point average as a criterion, the best fit equation included pre-clinical grade point average at the time of selection, high school percentile rank and grade in botany.

A study which was designed to investigate the influence of teacher-centered vs. student-centered methods of instruction in biology core classes, was conducted by Butler and Boyce (1967). Two classes were selected as samples, one being taught in the traditional lecture-demonstration-discussion manner, and the other in a more student-centered manner, utilizing teacher-student programmed instruction. Standardized pre- and posttests for measuring achievement and personality factors were administered to both groups. The results indicated that both groups made significant gains in achievement, but only in the experimental group did personality factors such as intellectual efficiency and self-assurance change significantly.

From this section of the review, we can see that definitive efforts have been made to determine the kinds of achievement characteristics that a person would require for success in subsequent learning experiences in college science. There is, also, some relationship between the kind of instructional technique utilized and the resultant achievement and other personality variables. There is, however, a considerable amount of redundancy in the studies reviewed, so that it would be impossible from the evidence to indicate the achievement ingredients required to produce a high level well educated science major. Also there is not enough specific evidence to indicate any single identifiable relationship between the organizational scheme of a science course and the achievement of the learners. Both of these considerations, namely, the relationship between types of prior achievement and subsequent learning experiences, and the relationship between the teaching process and types of achievement should be studied in great depth.

SCIENCE AND SOCIETY

Wood and his co-workers (1966) analyzed the scientific and technological content of a sample of state and capitol-city newspapers for a six months period in 1964 through 1965. They found that most of the articles were technologically based and dealt with medicine, general science, space technology, nuclear energy, and automation-cybernetics, in decreasing order. In two out of every twelve articles, processes of science were discussed with experimentation the most frequently mentioned. About 25 percent of the articles included some concern about science and technology from a social, political or economic point of view. Ninety percent of the science knowledge required for understanding the articles came from the disciplines of biology, physics, and astronomy. Such studies as these, done by people concerned with scientific literacy, indicate that a great deal of change is required in the college training of students in science courses intended as general education.

A study was conducted by Fredenburg (1965) to determine whether student interest in the physical sciences would be enhanced in a general educational physical science course if the course were oriented around everyday events or if it were oriented around a historical-logical subject-matter approach. Analysis of covariance was used to analyze pre- and posttest scores on an interest questionnaire developed by the investigator. Separate analyses were made for a number of time sequence arrangements for the two teaching methods. In none of the sub-studies was a significant difference in interest change found with either of the methods studied. Fredenburg, therefore, concluded that there would be no difference between the every day approach and the historical-logical subject-matter approach.

Pelham (1966) analyzed college level science courses in general education. His main goal was to produce guidelines for judging the intended results of science courses. He desired to determine what the courses did for the non-science group. Nine categories of results were suggested. They were: (1) to affect general science actions, (2) to alter student conceptions of social change where science is incidental, (3) to alter student views of social change by consideration of the aspects of science, (4) to alter student philosophical consideration through knowledge of the aspects of science, (5) to alter student philosophical conceptions where science is incidental, (6) to alter student conceptions of the nature of science, (7) to alter student functional capacities for action through contact with science, (8) to alter student functional capacities where science is incidental, and (9) to give student knowledge which is intrinsically valuable. Two courses of study were analyzed by Pelham using this scheme.

Pella and his co-workers (1966) sought to establish a working definition of the term "scientific literacy" by making a content analysis of available documents where in one or more references were made to the term. A search of the literature from 1946 to 1964 revealed one hundred items from which it was concluded that a scientifically literate person could be characterized as one with understandings of: (1) The interrelationships of science and society, (2) the ethics which control the working of the scientists, (3) the nature of science, (4) the basic concepts of science, (5) the differences between science and technology, and (6) the interrelationships between science and humanities. The above categories are given in the order of decreasing frequency of appearance.

A study which is relevant to the objectives of science teaching for general education was conducted by Tichenor (1965). He analyzed distribution of scientific knowledge within the adult population of the United States and further studied the characteristics of mass-media exposure and science attitudes related to amount of scientific knowledge. Data provided by secondary analyses of opinion polls since 1940 were analyzed using a field theory model of life space. Factors indicating higher scientific knowledge were: amount of formal education, occupational status, and extent of exposure to science news. Membership in educational groups and amount of exposure to science news seemed to display an interactive relationship at lower levels of education. Amount of science knowledge was strongly associated with the number and type of magazines preferred. The type and number of T.V. programs watched and newspapers read were less indicative of a subject's depth of science knowledge, and the type of radio program listened to was least indicative. Science attitudes seemed to be positively associated with science knowledge for all educational levels.

Staud (1967) determined the characteristics of and changes in material covered by texts used for college zoology instruction in the United States from 1790 to the present. Analyses of books were done on the material presented compared to the space allowed it, the sequence and treatment of materials, and on the objectives stated by the author. Two major time periods were identified. The period 1790 to 1875 was designated the period of natural history, while that subsequent to 1875 was called the period of zoology. Specific trends within those periods and sub-periods were identified. Findings suggest that text changes fail to keep pace with advances in science education and current needs throughout this historical period.

Wittmer (1967) developed a narrative historical survey of the religious characteristics of American geology textbooks of the 19th century. This study established the notion that the study of geology moved from directed support for Christian revelation to a completely secularized view with the growth of scientific advances. Both the use of geology as a science and the changing religious climate in the United States are discussed.

Liem (1965) conducted a historical study of science education in Indonesia. Using both library based materials and questionnaire data from Indonesian nationals, some specific factors were identified as being important in influencing the development of science education in that country. These were the nature of the Dutch-centered colonial education system, the adaptation of curricula and teaching methods from the colonial to the present system, the method of the financing of science education, and the role of American science educators as consultants. Guidelines for future development in Indonesian science education projects were discussed.

In this section, studies related to science as it is related to society, both in terms of what society knows of science, and also in terms of what society requires in general education in science were presented. There is insufficient evidence from the studies of the needs of society to be able to draw up a specific curriculum for general education science courses. However, trends presented here indicate that general education science courses should be constructed to fulfill the particular needs of society, rather than to follow specific trends within science itself.

ADMINISTRATION AND SUPERVISION

Siebring (1965) compared American institutions of higher learning on the proportion of students who earned baccalaureate degrees in chemistry who later obtained Ph.D. degrees in chemistry or bio-chemistry. He found, for the period 1947-1955, that when institutions were ranked on the ratio of Ph.Ds produced nationally to the number of chemistry majors who received Ph.Ds in that institution: (1) technical institutions ranked first, followed by universities and colleges, (2) Ph.D. granting institutions were more productive than those not offering doctoral work in educating students in chemietry at the undergraduate level, (3) private non-religious oriented institutions were productive. Siebring also stated that these data are in line with the assumption that institutions which enjoy national recognition have greater Ph.D. granting ratios, than those which do not enjoy such recognition.

The hypothesis that considerations other than scientific ones determine the extent of the United States Federal Government's support of college based physics research was tested by Castro (1967). He suggested this hypothesis because the vast majority of physics research is Federally funded and shows an emphasis by the government on studies which are pertinent to federal programs such as the military or space investigation rather than on theoretically oriented studies. The physics literature was analyzed to determine which studies were Federally funded and which were theoretical as opposed to experimental. Castro found that the frequency counts within the above categories show that physicists obtain support more frequently for experimental studies than for theoretical studies. Frequency counts of citations of research results in journals revealed that American theoretical work is considered more useful than experimental work. Castro also supplied evidence indicating that specific mission oriented research has the effect of moving the physicists accepting that particular kind of support away from the main stream of physics research, and that Federal support decreases the numbers of physicists available as classroom instructors.

EVALUATION AND EDUCATIONAL OBJECTIVES

In this section, studies are grouped as follows: those dealing with duplication of instruction between elementary or secondary schools and that on the college level; those studies which relate prior learning with achievement at the college level; those studies which deal with university and college professors' self evaluation.

Lander (1966) developed a checklist of chemical instructional items from indices of popular chemistry textbooks. These were validated by teams of teaching experts both from colleges and high schools. The validated lists were distributed to a random sample of college and high school chemistry instructors from the states of New York, New Jersey, and the six New England states. Respondents were asked to indicate whether or not a topic was taught at all, taught in depth, or merely mentioned. Lander found that what he terms "a tremendous amount of duplication of topics." Frequency counts showed that more than 50 percent of the items listed were taught or taught in depth by both categories of respondents. Recommendations for topic allocations for high schools and colleges were made.

Johnson (1965) suggested that there is too much duplication of instruction in physics from elementary school through college. He presented the same material to be learned about sound, electricity, and magnetism to a sample of students from junior high school, high school, and college. He found that achievement scores differed so little that students who complete a ninth grade general science course are not likely to greatly increase their understanding of the principles taught in this study in further course work. The studies of Lander and Johnson indicate that the relationship between instruction at the elementary and secondary levels and instruction at the college level should be made clear. Specifically, there should be a great deal more liaison work between teachers in the lower schools and teachers at the university level to prevent over duplication, with its motivation reducing effects.

Three studies related prior achievement in high school to college level achievement in specific science areas. Finger and his co-workers (1965) conducted a statistical analysis of the inter-relationships among: college physics course grade, overall grade point average, college examination board verbal and mathematical scores, academic motivation, sex, and type of high school physics course taken. He studied students in introductory physics courses at Brown University in 1963-64. The data were analyzed with high school physics preparation categorized as PSSC, conventional, or none. Analyses of variances on various scores for those groups showed that PSSC students had higher SAT-M scores. When grades in other courses were used as a standard for predicting expected performance in physics, the PSSC group showed a slightly better physics grade, significant at the five percent confidence level. When students were grouped by sex, it was found that girls had lower physics grades than boys. Using discriminate analysis on the three groups, two discriminants emerged. The first involved high performance in other courses, and high SAT-M scores with low performance in physics. This discriminant appeared to separate groups by sex. A second discriminant associated high performance in physics with high SAT-M, but with low performance in other courses. This discriminant appeared to differentiate on the basis of previous instruction in physics. The PSSC group scored highest for boys and girls, and the no-previous physics group was lowest in college physics achievement. The discriminant analysis detected differences were not judged by the researchers to be reliable. Finger and his co-workers concluded that the group differences do not indicate that PSSC is an advantage as a preparation for college physics.

A survey questionnaire study of college physics departments was conducted by Renner, Whitaker, and Bautista (1965). The questions asked were: (1) Do colleges consider high school physics courses as being valuable enough to grant advance standing in college physics, or to change the type of beginning physics course the student will take? (2) What are the views held by the college physics professors as to the value of high school physics? The questionnaires were distributed in 1959, and again in 1964. During the interim period, PSSC Physics was widely publicized and adopted in many high schools. The majority of the responses for both time periods indicate a large number of college physics departments are not in favor of developing special physics courses for those students who have had high school physics. Questionnaire responses indicated that college physics departments seem to prefer to continue the type of physics course that PSSC was designed to replace. A need for innovation in the teaching of college physics was presented and discussed in depth.

Rozolis (1966) sought to determine the extent of interaction, as well as the relationships, between the biological science courses taught in Los Angeles County, California, notably the BSCS program and newly developed introductory biology courses at the University of California at Los Angeles. He found that newer courses at both levels were subject matter oriented and less oriented toward the learner and society. He also suggested that the newer courses were more inductive and less deductive than their respective predecessors. Notable in his findings were that both the high school courses and the college courses investigated were independently developed, both from one another and from that which went before them. Evidence presented indicated that the newer college courses investigated not only were not patterned after the BSCS curricula, but also that they were influenced greatly by the existence of the BSCS curricula. Strikingly then, Rozolis found that, in this area, newer developments in the university and high school biology curricula were separate phenomena, and had evolved from separate considerations in educational systems which had not cooperated, nor, indeed, even interacted. From these studies on the relationship between prior learning and later learning at college and university levels, it has been found in most cases what goes on at the university is independent of what goes on at educational levels below it. Perhaps the reverse is also true. Hence, it is strongly recommended that cooperative studies be made of curriculum in order to determine not only a reasonable grade level at which particular educational objectives in science should be pursued, but that specifically measured achievement goals be developed cooperatively.

A number of innovations have been made in testing and in the use of tests as educational devices. Shell (1966) evaluated the influence of interim testing on immediate achievement and retention of material about atomic structure in a college general science course. Two classes were administered tests. One of the classes received 10 interim tests, while the other had no such test. The same pre, post and retention achievement scores were collected for both groups. Shell found that the interim test groups achieved significantly higher than those who did not have these kinds of tests. Also, within each ability group of each treatment group, measured by the STEP science test, the interim group achieved significantly higher. Shell found the same trends on retention testing.

Open-ended and multiple choice tests in general physics were compared by Kruglak (1966). During one semester five tests were given, each of which had both multiple choice and essay sections. The essays were graded on a previously constructed key by four instructors. Test reliabilities were calculated by split-half and Hoyt methods. Product moment correlation was employed to compare essay and multiple choice sections of the experimental tests, as well as to assess the reliability of essay grading. While the reliability of all tests was low, the reliability of the open-ended tests was higher than that of multiple choice tests. Grading reliability between different raters of essay items was high. Recognition of definitions correlated highly with ability to solve numerical problems. Multiple choice scores correlated highly with course grade, but there was little correlation between recognition tests and laboratory grades.

Scales (1966) investigated grading practices in a college natural science course taught by four different instructors. Under conditions where the instructors met to define course objectives to agree upon common course procedures, and to construct common mid-semester and final examinations, course grades were less liberally assigned than when each of the instructors was free to set objectives and to develop his own evaluation scheme independently. Scales concluded that a "meeting of the minds" approach seems to be helpful assistance to course instructors in developing practices.

Easley and his co-workers (1967) reviewed the contents of thirteen standardized biology tests currently in use in an evaluation of student achievement in college biology. Most of the tests reviewed were heavily loaded with morphology and physiology interrelationships. These workers suggest that tests developed in the future should make greater use of questions requiring the interpretation of data.

Appleton and Haab (1966) summarized information obtained from a large number of colleges and universities, medical schools, pharmacy schools, dental schools, on the content of the first course in bio-chemistry. The purpose of this survey was to present information needed for the revision of American Chemical Society cooperative bio-chemistry tests.

Smith (1966) developed a method of teaching elementary college geology using a computer based testing program. In his course, the computer was used to score examinations, to print reports to students given them specific advice on strengths and weaknesses, to report scoring efficiency to the instructor, and also to select and print examination items.

Walker (1967) attempted to determine what qualitative characteristics of a chemical equation can be used to develop a method for predicting the difficulty a group of students will have in balancing it. He found that these characteristics were both the sum of the coefficients of the balanced equation or the sum of the logarithms of the coefficients of the balanced equation.

Several studies analyzed related to measurement of specific content of attitude. Adler (1966) determined the kinds and extent of changes of learning of concepts of time, space and matter for college students. Using gain scores on a specifically developed achievement test, she found that courses in science orientation or physical science contributed significantly to gains, whereas course work in biology or maturation alone, did not contribute to the knowledge of time, space and matter. She also found that the development of these concepts is positively influenced by the number of years of high school science taken, and most specifically developed by having had a high school physics course.

Using a case study technique, Chambers (1965) studied the conceptual development of 24 college freshman using a unit on vertebrate embryology in introductory biology. Case studies were analyzed to determine the attainment of major concepts and of sub-concepts. Using a Kolmogorov-Smernov test, student responses to instruction were shown to be divergent rather than convergent. A similar technique showed no uniform rate of change in conceptual development. Significant but small rank order correlations were shown to exist between background information in science, science ability, verbal ability, and conceptual attainment. Concept attainment was not significantly correlated with numerical ability, number of years of high school science, or socio-economic status.

Lamb (1965) constructed and administered an achievement test to entering college chemistry students to determine if those who had had prior instruction in chemistry differed significantly from those who had not. Significant differences were detected between those groups using analysis of variance. When achievement scores of entering students in freshman chemistry were compared with the scores of their high school teachers, a significant correlation was found on a number of concepts on the achievement test.

Mitias (1967) investigated the overt problem-solving behaviors of a sample of 30 prospective science teachers. The sample was fairly homogenous, consisting of limited ranges of age, subject matter, preparation, and number of credit hours in respective majors. From a pilot study, a data category system was emperically developed. It consisted of goal clarification, situation analysis, procedure planning, procedure execution, random manipulation, and irrelevant behavior. Subsequent analyses of data were made on a three-dimensional pattern of sequence of categories of behavior, frequency of each category, and number of categories used. Graphical interpretation of data showed that for a particular problem, there existed several patterns of problem-solving and that for a particular individual, patterns of problem-solving differed from one problem to another. Statistical analysis showed that problem-solving patterns were not peculiar to individuals with a given academic major such as science, nor significantly different for groups with majors in biological sciences compared with those in the physical sciences.

Butz (1965) studied a relationship between problem-solving behavior and knowledge of science facts. He utilized a sample of 21 college seniors taking an elective methods course in elementary school science. Science knowledge was measured by the STEP Science Test. A test in problem-solving was developed by the investigator in which two separate problem situations were presented along with more information than necessary for reaching a conclusion. The subject was required, then, to select the relevant material and then select a conclusion from among a number of alternatives. Scores for phases of the problem-solving test were compared to scores on the knowledge test using product moment correlation. A significant correlation was found between problem-solving behavior and specific knowledge content. The investigator suggested that the value of this particular study rests in the development of an instrumental means of measuring problem-solving behavior.

Whiteman (1965) compared attitudes towards conservation of biology students in two categories. Those who had had a semester biology course specifically designed to contain a unit of five weeks duration on the fundamentals of conservation and students in a traditional semester of biology which omitted conservation. Attitude change toward conservation was measured for both groups using a Lickert type scale in pre- and posttest settings. It was found that there was an attitude change for the conservation group significant at the one percent level of confidence when measured by a t test. The non-conservation group did not show such an attitude change. Demographic variables, sex, and life experiences were also analyzed to determine if they were related to conservation attitudes.

Teacher self-evaluation was studied by Simpson (1966). He investigated the self-evaluation practices of nearly 300 college instructors in physical science from 76 teacher-training institutions. Respondents were asked to rate the usefulness of each of 17 kinds of self-evaluation tools, tools such as tape recordings of classes for later analysis of teaching. He concluded that the use of self-evaluation was fairly widespread among the respondents. Those self-evaluation tools, however, which had the most widespread use were not necessarily those which the instructors judged to be most effective. While most instructors were familiar with a few self-evaluation tools, they generally were unfamiliar with the wide variety of those tools available.

TEACHER AND STUDENT CHARACTERISTICS

Several studies dealt with characteristics of undergraduate students. Nathans (1967) studied why students withdraw from chemistry courses in junior college evening schools. Using questionnaire data, Nathans concluded that students withdraw from evening school chemistry courses in junior colleges studied for two main reasons. First, that they did not study enough, and second, the course was far too difficult for them. The remedy lies in better and more relevant counseling and in meaningful entrance requirements for such courses.

George (1967) investigated the differences in critical thinking between science education college seniors and college seniors in other specialty areas of education. Using the Watson-Glaser Critical Thinking Appraisal, scores were analyzed by analysis of variance. He found that science majors did significantly better than all groups tested, except for mathematics majors. Using the Bartlett test for homogeneity of variance, the science majors were shown to be the most homogenuous group on their critical thinking scores.

Butzow and Williams (1965) developed and tested the discriminating ability of a 20 item instrument for measuring the differential strength of science interest. The items consisted of phrases descriptive of scientific behaviors of professional scientists. Responses were recorded using three semantic scales of Osgood's instrumental technique which were: important-trivial, potent-impotent, and active-passive. The item responses were compared for men and women college freshmen at separate institutions. Using Chi square and t tests to find significant differences between students registered as either science majors or non-science majors, all three response scales of six of the items, mainly in the physical sciences, were judged to provide the type of discrimination sought. Williams and Butzow (1967) further examined the characteristics of their science interest instrument in several ways. The interest test responses of a sample of 25 randomly selected entering male freshmen at the University of Rochester, when subjected to emperical grouping analysis, produced three groups, identifiable on the basis of orientations to physical science, molecular biology, and medically oriented biology. Comparisons of test measured achievement in science with interest item scores were made for a sample of 247 male freshmen. No significant relationships were found between achievement and interest categories by rank order correlation. Semi-structured interview data were compared with the interest responses for 18 freshmen science majors. For the majority of those science majors, those two estimates of science interest were coincident.

Several studies of the characteristics of graduate students were made. Synder (1965) tested the hypothesis that the more institutionized a science is, the more homogeneous and higher are the mean statuses of origin of the members, the higher are the mean salaries and fees obtained by them, the higher is the societal prestige of the science, and the higher is the mean proportion of dropouts in training to enter the science. Using relevant data gathered from 1600 graduate students from universities on the eastern seaboard, in the fields of physics, chemistry, biology, psychology, economics and sociology, no significant concordance was found between the variables considered. Synder concluded that graduate students seemed to come from a markedly similar social strata.

Strauss (1965) conducted a comprehensive study of those obtaining doctorates in the United States during 1957. The study cataloged a large variety of academic and social characteristics showing trends within fields as well as comparisons between fields. Subjects with doctoral degrees held a number of traits in common. They were well above their peers in I.Q., in secondary school science achievement and secondary school mathematics achievement. Their fathers had come from professional and managerial occupations. A striking finding was that high school was not a particularly crucial time of decision in determining their future career goals. Most decided on their careers late in their undergraduate work or early in their graduate training. In a later study, Strauss(1966) sought to establish the characteristics of a trait he called "research ability" through semi-structured interviews of 96 American and 66 European professors from the sciences and humanities. Content analyses were made of interview tapes to produce summary statements. He concluded that research ability was seen by these professors as a specific but complex trait among successful doctoral students. The chief elements reported were: interest, intelligence, industry, information, initiative, imagination and integrity. These professors felt that these traits are best manifested under trial research situations and then are best observed through close personal contact.

Two studies dealing with the characteristics of teachers were reported. Carpenter and his co-workers (1965) studied the interrelationship of such college teacher types as pragmatic, authoritarian and friendly counselor with subject matter areas. Teacher trainees were asked to select descriptions of teacher types that they felt appropriate to particular kinds of college situations such as teaching, coaching, etc. Data trends suggested that correspondence of traits between situation and instructor exist. No single type of instructor was specifically preferred for all situations.

SUMMARY

While many aspects of science were considered in the areas reviewed, one consideration remains paramount. Many phases of science teaching were compared by studying groups using varying approaches to learning in which treatment groups were compared on a common achievement test. This experimental procedure is questionable because the treatment differences often are large enough to produce designs which are, strictly speaking, not comparable because they have different objectives. Often, however, no significant differences between treatment groups are reported. This type of information is not very helpful in deciding whether or not to use a particular approach for teaching science at any level, particularly at the college level.

Needs for later research are: specific experimental teaching situations in which the achievement of the students is not compared to the achievement of students using some other kind of teaching approach, but rather where the achievement is compared to what is expected from the particular approach being used, and on that basis, and on that basis alone, it should be judged.

Another important question raised in these research studies is that of the relationship, if any, exists between science courses at levels below that of college, and science courses at the college level. Science courses, notably the PSSC physics approach, and the BSCS biology approach were compared to courses in physics and biology at the college level. No specific findings were revealed here as to the influence of the newer approaches to high school science teaching on the teaching and learning of science at the college level. This kind of research should be undertaken in such a way that the objectives of the newer courses developed for high school science are compared both with the kinds of achievements desirable for those entering college courses in science, and also the objectives which have been and which are being developed for those college level science courses.

It was found in several studies that college level personnel were either ignorant of, or were oblivious to the developments in science teaching at the high school level. If the investments which were made from Federal funds are going to bear fruit and improve science instruction in this nation, the relationships between those costly secondary programs and the now developing college programs need to be very carefully studied.

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